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METHODOLOGY INVESTIGATION
FINAL REPORT
AUTOMATION OF INTEROPERABILITY
TEST DATA ANALYSIS

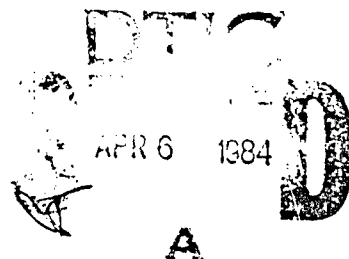
BY

L. CLAUDIO

APRIL 1984

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REPLY TO
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SUBJECT; Final Report, Methodology Investigation for Automation
of Interoperability Test Data Analysis, TECOM Porject
No. 7-CO-RD2-EP1-001

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GROVER H. SHELTON
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Analysis Directorate

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FOREWORD

The Jet Propulsion Laboratory, Pasadena, California, assisted in the preparation of this document under Contract Number DAEA 18-82-F-3551, Modification 04 dated September 22, 1982.

SECTION 1. SUMMARY

1.1 BACKGROUND

a. The Army and the Department of Defense (DOD) have developed and are continuing to develop a number of major automated Command Control, Communications, and Intelligence (C3I) Systems. These include TACFIRE, MCS, TCAC, TCS/TCT, AN/TSQ-73, REMBASS, and ASAS to name a few. These systems are designed to interface with a large number of interactive systems and to operate in a highly interactive environment. A critical element in the success or failure of these C3I systems will be their ability to interoperate and perform under load in a highly interactive tactical environment.

b. The nature of interoperability testing is such that large volumes of data are generated. This, in turn, leads to the requirement for an automated data reduction and analysis capability since the cost of manual data reduction and analysis in terms of both dollars and test personnel is prohibitive. Additionally, the probability of errors in manual data reduction and analysis further supports this requirement. The Army is developing major systems with a critical role in the combat effectiveness of the future Army in the field. The possibility of failure to analyze and evaluate the data generated in interoperability testing is a risk that the Army cannot afford to take.

c. The Interim Test Item Stimulator (ITIS) is a message loading system used by the US Army Electronic Proving Ground (USAEPG) for development testing (DT) of these automated Army systems. The requirements for the ITIS were articulated in mid 1979 and a generation of software to meet those requirements was begun at that time. The ITIS consists of three distinct parts; the pre-test functions, real-time functions, and post-test analysis functions. However, the ITIS does not provide a truly automated post-test analysis capability.

d. This report provides a synopsis of the known efforts toward automating the data reduction and analysis of interoperability test data.

1.2 OBJECTIVE

The objective was to develop comprehensive and cost effective methods for reducing and analyzing the large volume of test data generated during interoperability testing of automated communications-electronics (C-E) systems. Specifically, two sub-objectives are addressed:

a. To determine current tester needs for automation of interoperability post-test data analysis.

b. To propose an appropriate approach for the automation of interoperability post-test data analysis which would provide an effective method for reduction and analysis of typical test data from a large data base generated during interoperability testing.

1.3 SUMMARY OF PROCEDURES

a. The procedures used to identify, isolate, and resolve technical problems in the course of performing this investigation included interviews

with US Army test personnel, reviews of pertinent documents and contacts with outside vendors. The scope was limited to examining only a select number of systems with emphasis on the Maneuver Control System (MCS) since that system is an executive system within the Army Command and Control System (ACCS) architecture; USAEPG has familiarity with the MCS owing to recent tests.

b. Interviews were conducted with personnel at the Field Artillery Tactical Data System (FATDS) Software Support Group (SSG) at Fort Sill, Oklahoma to determine present post-test data analysis capabilities at FATDS SSG, and to identify and acquire applicable documents.

c. MCS specifications, Required Operational Capability (ROC) documents, relevant Independent Evaluation Plans (IEP), and Test Design Plans (TDP) were reviewed to determine interoperability and other test requirements for the MCS as well as post-test data analysis requirements.

d. Contacts with outside vendors included presentations by companies supplying state-of-the-art relational data base systems and suppliers of air defense test hardware and software. The test hardware and software included real-time, quick-look, and post-test analysis capabilities.

1.4 SUMMARY OF RESULTS

a. The Army Battlefield Interface Concept (ABIC) identifies the interfaces for each Army system. For MCS alone, there will be numerous interoperability tests performed in the next three to four years. The MCS must be able to interoperate successfully with up to fifteen other systems. MCS interoperability testing must be done for multiple levels of loading ranging from no load up to worst case loading. Data item requirements include:

- (1) data on transmission errors
- (2) format errors
- (3) transmission delays
- (4) central processing unit (CPU) demands
- (5) message volume
- (6) translation/reformat times
- (7) response times for information requests for each interoperating system

b. Post-test analysis performed at the FATDS SSG was found to be basically manual with some automation in their single thread, single function tests. The single thread, single function tests consisted of sending the software under test each TACFIRE message, one at a time, and checking to see if the correct response was received (in many cases the correct response was a simple acknowledgement).

c. Review of the present ITIS functions and procedures revealed two specific weaknesses with regard to automation. First, the post-test analysis system is labor intensive, requiring detailed planning and a large number of inputs by an operator for each analysis product (output) requested. Second, the message scenario tape (MST) generation is also labor intensive. The MST generation relies on an ITIS unique data base, and there is no direct tie between the MST, the message log tape (MLT), and post-test function. Of concern here is the relation of the MST to the post-test function, that is, did the scenario execute as planned?

d. Current tester needs are summarized as follows:

- (1) Quickly and easily be able to define the data and enter it into a computer.
- (2) Quickly and easily retrieve data based on selected filters (attributes).
- (3) Quickly and easily be able to define and output the required graphs and charts.
- (4) Be able to automatically conduct statistical analyses on the outputted information.
- (5) Be able to compare results from different tests; also, be able to compare results from tests performed at one point in time with version "x" software to tests performed at another point in time with version "y" software.
- (6) Quickly and easily verify that the scenario was executed as planned or identify any differences if executed differently from planned.

e. Two approaches for the automation of interoperability post-test data analysis are proposed. The first approach uses the current post-test analysis system (PTAS) software to the maximum extent, along with a pre-defined runstream (in VAX terminology, a command file) to automatically generate the desired product (output). The runstream is a set of computer commands which replaces the normal (redundant) PTAS operator entries. The second approach is predicated on the introduction of a commercially available data base management system (DBMS) which includes a query and embedded query language. The query language is used in place of the PTAS software to do the data retrieval.

1.5 DISCUSSION

a. Interoperability testing, as experienced with MCS, has produced large quantities of data requiring analysis and reporting. No relief on the voluminous data obtained is foreseen as more and more systems are linked together and interoperability testing continues. Automation of test data analysis must be pursued to effectively utilize and analyze the voluminous data. The ITIS can provide information on transmission errors, format errors, transmission delays [as seen by the ITIS at the system under test (SUT)-ITIS interface], message volume, translation/reformat times (SUT-ITIS interface), and response times (SUT-ITIS interface). To obtain information about CPU

demands, software instrumentation other than the ITIS, such as hardware or software monitors, is required. The added instrumentation could also be used if intrinsic information on transmission delays, translation/reformat times, and response times are required to isolate the cause of any delays or bottlenecks within the SUT. The ITIS PTAS does not currently have the capability to accept information from additional data sources for correlation and analysis. Such a capability would further enhance ITIS for automation of test data analysis.

b. The method used by the FATDS SSG, that is to identify the correct response from a SUT given a particular message was inputted, is another means for automation of test data analysis. If a SUT is working reasonably well, the amount of "good" data received may bury those anomalous data; this method would aid in sorting and identifying those anomalous cases. The method needs to be expanded to handle multi-thread, multi-function tests. TACFIRE, for example, is a case where the correct response to a given message stimulus is dependent upon configuration.

c. The ITIS PTAS is a step towards automation; however, it is labor intensive. The PTAS software is very flexible as to selection of inputs and outputs, but this flexibility means that a large effort is required to define the input tables for each analysis product desired.

d. Items 2 through 5 of the list of tester needs can be accomplished by use of a generalized data base management system (GDBMS) and is further discussed in paragraph 1.5e. Item 5 can utilize a GDBMS if measures of performance (MOPs) are defined and are part of the data base; hence, any performance difference due to software version changes can be examined by comparing the pre-defined MCPs. Items 1 and 6 need not use a GDBMS; user specified/generated programs can be used and tailored for specific SUT analyses and scenario design. Operating system utilities, such as the compare program on the VAX, could be used to determine differences from a planned scenario to that actually executed.

e. The use of a runstream to drive existing software as a proven method of automation is relatively straightforward and low cost to implement, as in this case where PTAS already is in existence. Although the runstream automates the manual procedures normally performed, changes to the desired output are not easily and quickly performed.

f. The use of a query and embedded query is a natural extension of the modern commercial data base systems. It provides for tabularization and other required data operations; the programming can be done by persons familiar with high order language programming. The test analyst does not have to define procedures when changes of outputs are required; the DBMS does it automatically, with the analyst specifying what he needs. Additionally, modern day DBMSs include data analysis/graphics packages, thereby alleviating the need to create a file for interfacing with yet another analysis package (PTAS interfaces with the DBMS statistical package). The use of DBMS with a query language is the logical evolution of the ITIS system.

1.6 CONCLUSIONS

a. There are no known completely satisfactory automated analysis systems for interoperability test data. Such a system is greatly needed to provide comprehensive and cost effective methods for reducing and analyzing the large volume of test data generated during interoperability testing of automated C-E systems.

b. The best approach toward automating interoperability post-test data analysis is the implementation of a GDBMS. This allows greater flexibility and capability than afforded by currently used interoperability data analysis means.

1.7 RECOMMENDATION

Use of a GDBMS should be pursued for use in automated post-test data reduction and analysis of interoperability test data.

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SECTION 2. DETAILS OF INVESTIGATION

2.1 INTRODUCTION

a. Two objectives to be considered when doing this methodology investigation are to determine current MCS user needs for automation of interoperability post-test data analysis, and to propose an appropriate approach for the automation of interoperability post-test data analysis for the MCS which would provide an effective method for reduction and analysis of typical test data from a large data base generated during interoperability testing.

b. There are numerous definitions of interoperability, of which two are given as follows.

(1) Interoperability (ref 1, app C): The capability to interact with existing and future information systems of ground combat, other services, and with the command and control systems of allied nations.

(2) Interoperability (ref 2, app C): The ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together.

c. Interoperability testing by the US Army is designed to evaluate the following elements (ref 2, app C):

(1) Message transfer compatibility, accuracy and timeliness.

(2) Adequacy of Table of Organization/Equipment (TOE) communications means to support message transfer between two systems, including communication net saturation during interoperability and non-interoperability; and adequacy of authorized equipment to satisfy interoperability criteria.

(3) Effects of noise from battlefield conditions, where noise is defined to be unpredictable electromagnetic radiation due to components, atmosphere, unintended systems coupling, or electronic countermeasure/electronic counter-countermeasures (ECM/ECCM) activity.

(4) Adequacy of operator training in effecting message transfer between systems.

(5) The detectability rate of two systems interoperating together. Detectability here and in item (8) means the ability to discover or find electromagnetic emanations and to extract information from them.

(6) The effect of data transfer messages on system processing time between two systems.

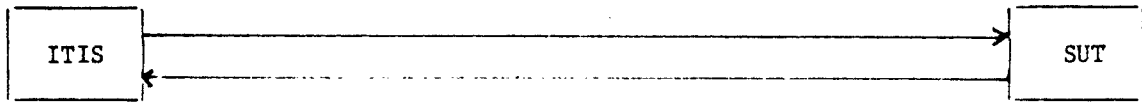
(7) The procedures that affect continuity of operation between two systems in the event of failure or shutdown of the primary means of interoperability.

(8) The functional utility of system-to-system data transfer on the basis of data communication enhancements, costs, detectability, and other trade-off factors.

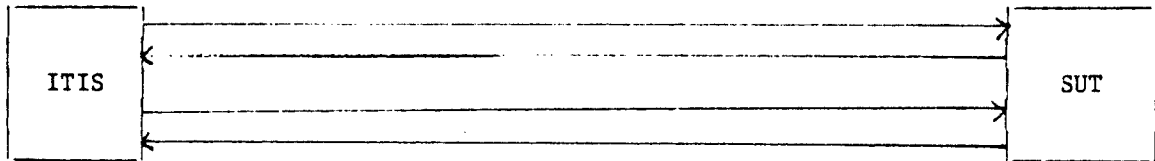
d. Testing can be done in a number of test stimuli SUT configurations. Four basic configurations are: single system, single threaded; single system, multiple threaded; multiple system, single threaded; and multiple system, multiple threaded. These four configurations are shown functionally in figure 1 (ref 3, app C).

e. One function of DT is to determine how well the SUT meets its performance specifications. Test plans are developed on the basis of the governing documents, including the ROC, Test Operation Procedures (TOP), the system A, B, and C level specifications, the IEP, and the TDP. After a test has been run, the test data are evaluated to produce indicators of system performance; data are summarized in descriptive write-ups, tabular form, time histories, histograms, and other means as required. After all testing is completed, a final report is issued to summarize system performance, including performance meeting or exceeding requirements, performance shortcomings, and recommendations.

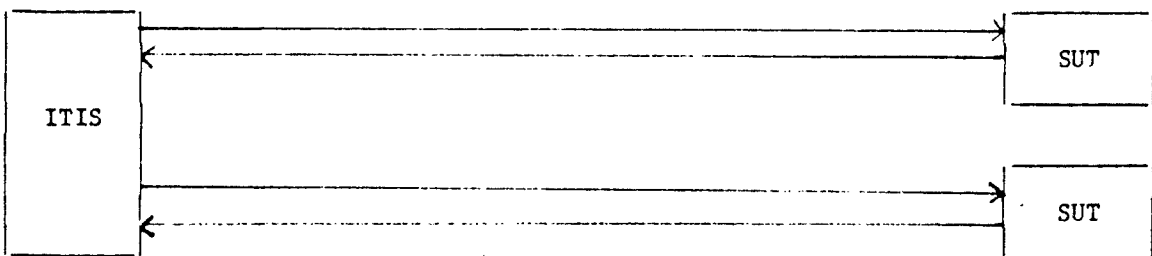
f. This section presents the detailed information used to support the conclusions and recommendations of the summary section (Section 1). This section includes information on current and proposed methods of post-test data analysis as background material, identification of MCS user needs for automation of interoperability post-test data analysis using mainly the currently available software and hardware; and a proposed approach in the event of a major change to a newer commercially available DBMS.



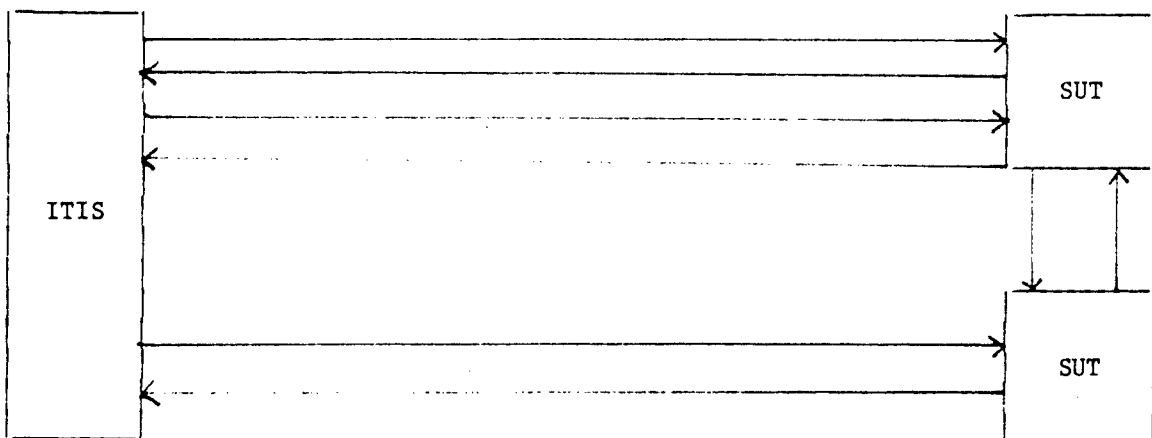
a. Single system, single threaded



b. Single system, multiple threaded



c. Multiple systems, single threaded



d. Multiple systems, multiple threaded

Figure 1. Interoperability test configurations.

2.2 METHODS OF POST-TEST ANALYSIS

In a consideration of automating post-test data analysis, one would naturally ask how it's being done currently at USAEPG, how it's being done on other US Army and military programs, and how it's being done on non-military systems or programs, e.g., at the Jet Propulsion Laboratory (JPL). The following information was gathered during two trips to Fort Huachuca (ITIS/MCS testing), one trip to Fort Sill (TACFIRE testing), and one trip to a vendor involved with testing of air defense systems.

a. ITIS/MCS Post-Test Data Analysis

(1) The MCS interoperability testing is done using the USAEPG ITIS. Figure 2 shows the functional configuration of the ITIS. As shown, there are three main functions: the pre-test system, which generates the message scenario tape (MST); the real-time system, which accepts inputs from the MST, exercises the SUT, and stores the test data to the log tape; and the post-test analysis system, which is used to analyze the data on the log tape. PTAS is the system of interest here.

(2) An earlier version of ITIS was to have had both the MST and log tapes as inputs to the PTAS, but the current version of the test system has the MST information included on the log tape and no direct input from the MST to the PTAS. This method should require that the MST information to be relayed directly through the real-time system to the log tape with no changes due to SUT-caused message delays or errors, else it becomes difficult or impossible to do valid evaluations of SUT performance, or to verify whether the scenario went off as planned.

(3) The current version of PTAS operates as follows. The PTAS user controls reduction of the data by entering control parameters at a terminal. The PTAS produces printed output in the form of dumps, tables, or plots, as requested; the system can also save the output to disk files to be used as input to a statistical program package. This package, which is not part of the PTAS, can be used to generate histograms and other statistical outputs. A functional representation of the post-test analysis system is shown in figure 3.

(4) The PTAS is run on a VAX 11/780 with the following peripherals: terminal, line printer, mag tape transport, and disk storage. The analysis of data by the PTAS is controlled by the specification of inputs for up to five control tables: format, primary variable or variable, dump, table, and plot. These tables control the data reduction and specify the output formats. An edit function allows the user to add or delete table entries. A functional representation of the control table operation for PTAS is shown in figure 4. Further details on PTAS usage are contained in the PTAS User's Manual (ref 5, app C), and are discussed in paragraph 2.3b(2).

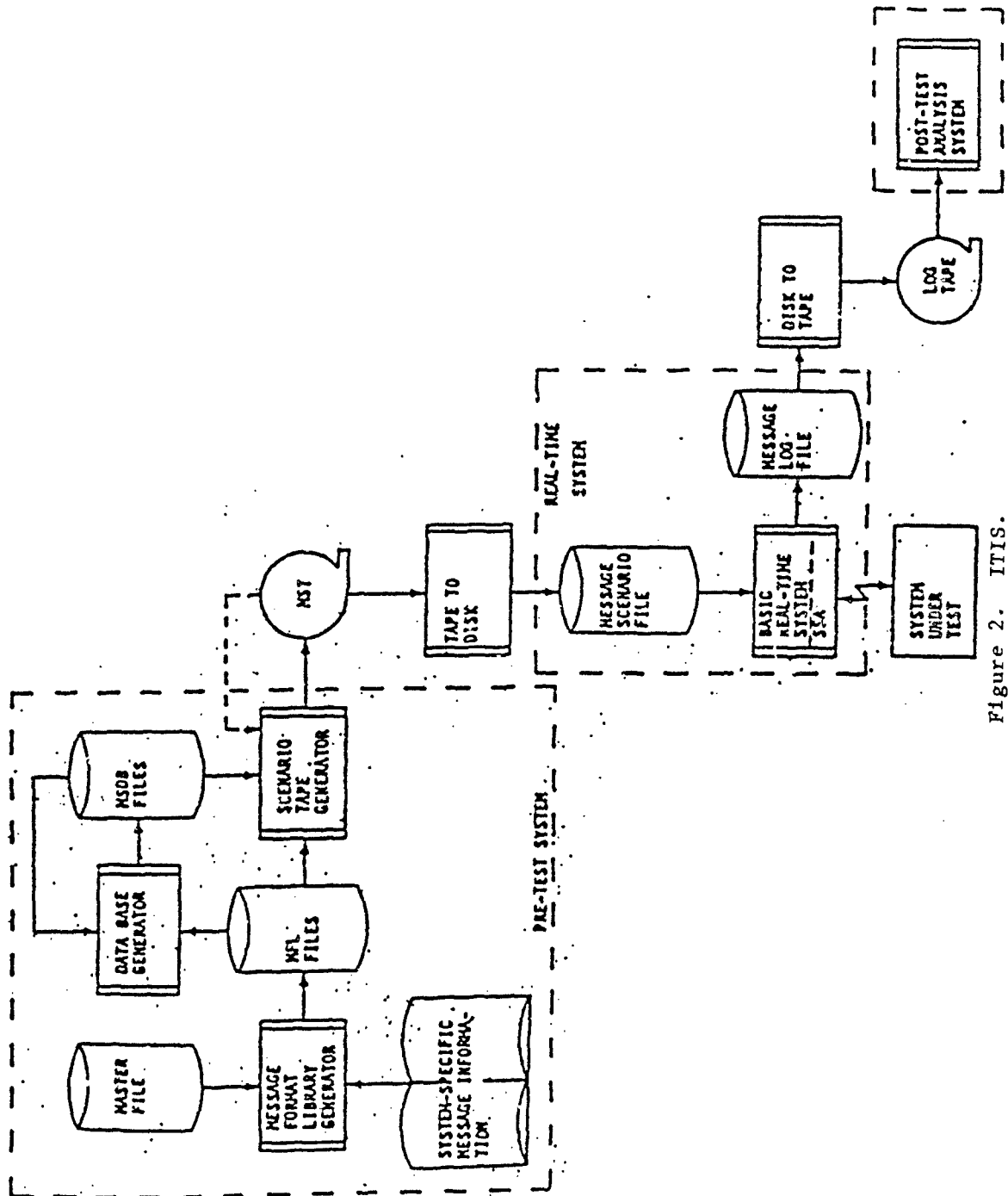


Figure 2. ITIS.

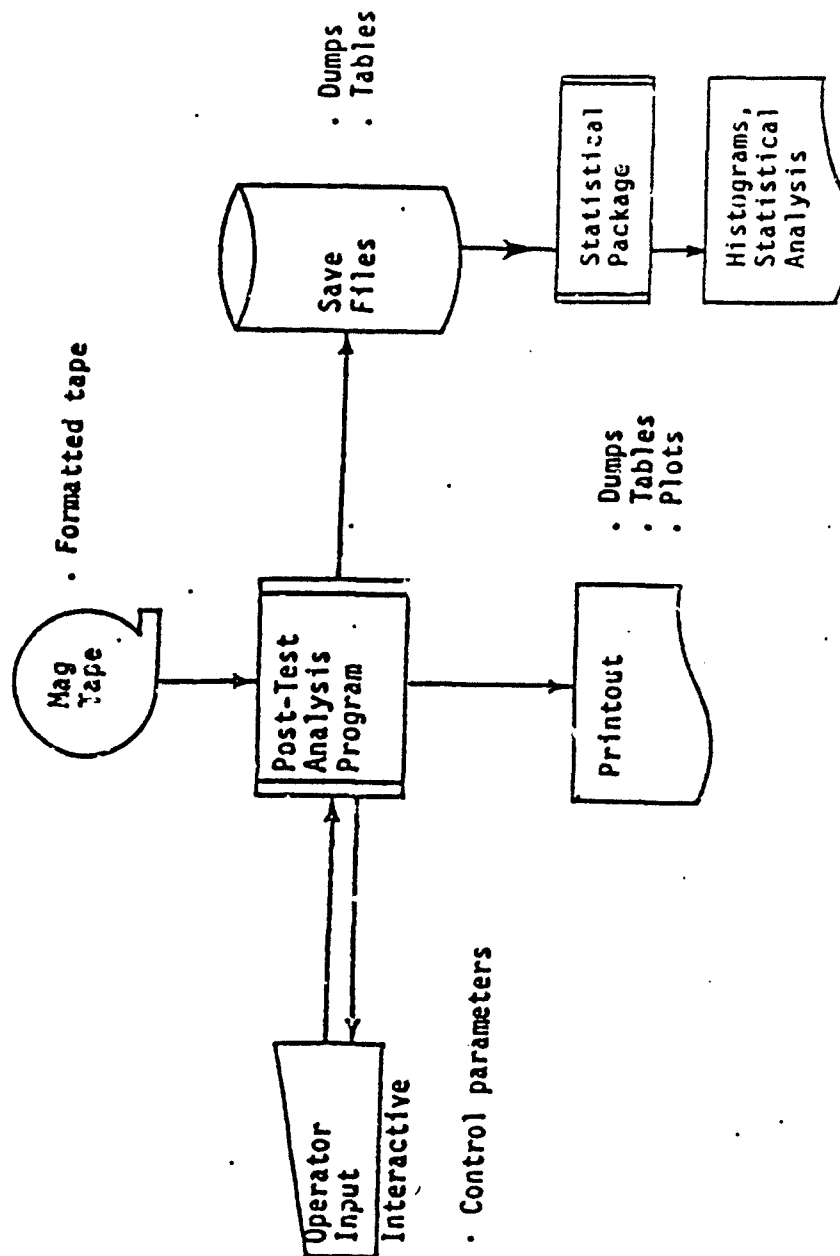


Figure 3. External data flow for the PTAS program.

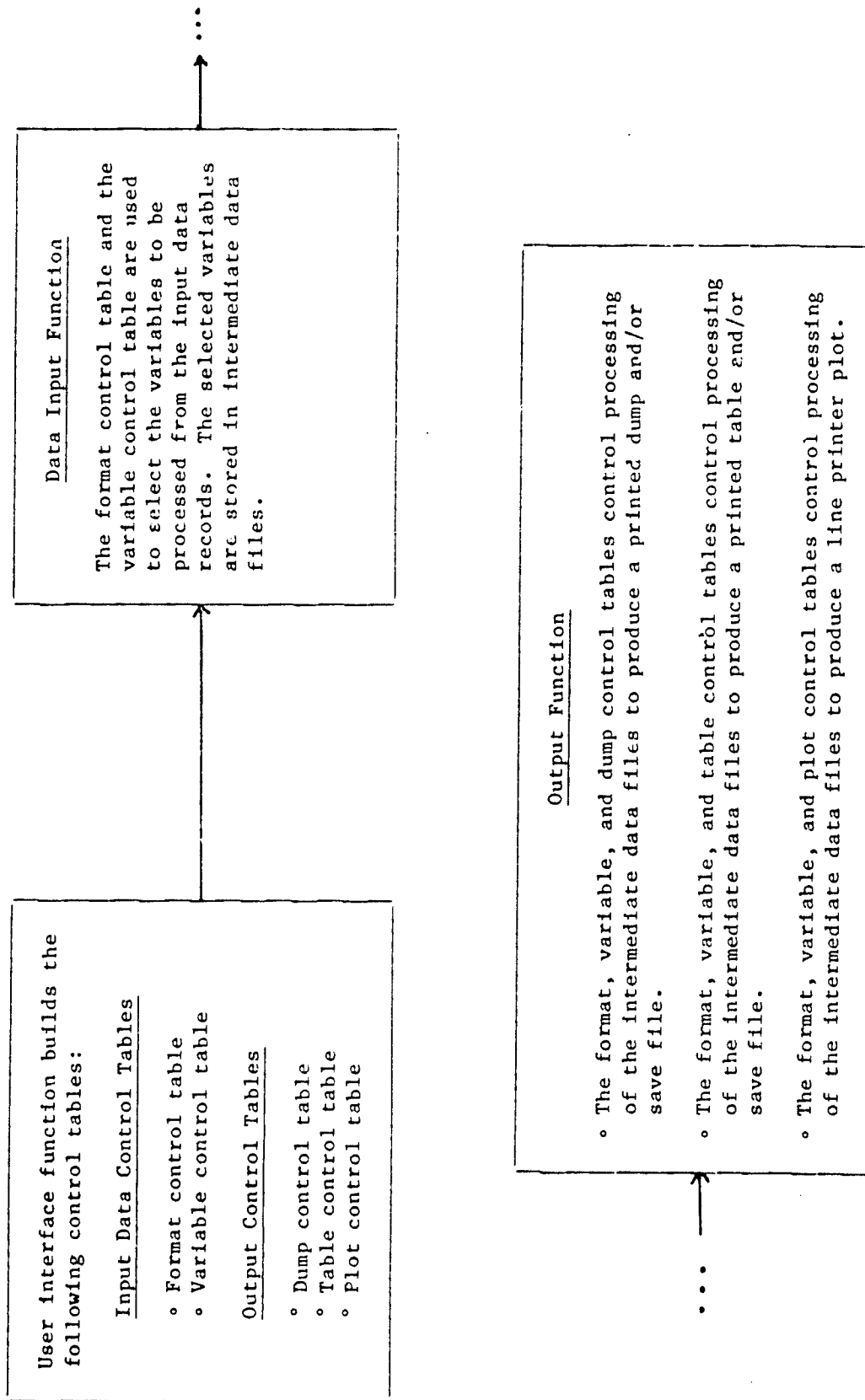


Figure 4. Internal data flow of the PTAS program.

b. TACFIRE Post-Test Data Analysis

(1) TACFIRE is a US Army command and control system that is currently being deployed with combat units. This system receives, stores, combines, and sorts target reports; receives targeting information; allocates firepower; computes ballistic firing data; and sends fire orders to field artillery weapons. TACFIRE's communications capabilities include conversion of standard field artillery messages to digital messages that are transmitted over standard Army communication equipment, automatic encryption and decryption of messages, and automatic relay of messages (refs 6 and 7, app C).

(2) The TACFIRE/FATDS Software Support Group (TSSG) at Fort Sill has responsibility for verification testing of post deployment versions of TACFIRE field systems. Verification testing of TACFIRE software programs is done to verify that required functional changes have been implemented, that the changes meet specified requirements, and that their implementation has not adversely affected the unchanged portions. Verification testing is done in four phases: Standard Operating System (SOS) test; Functional Area System Test (FAST); Benchmark Test; and New Version Verification Test (NVVT). TSSG analyzes the test data off-line following completion of each test phase.

(3) Analysis of the test results is accomplished manually by visual observation during the conduct of the test and by comparing printouts of errors/warnings, the transaction journal, and message traffic with expected outputs; and automatically by use of the TSSG FAST Compare program. Also, shortcomings, deficiencies, or unexpected results discovered during the conduct or analysis of any test are recorded on a Test Anomaly Report (TAR) and forwarded to the test director for resolution. Anomalies which cannot be resolved during the conduct of the test are recorded as TACFIRE Problem Reports (TPRs) for post-test resolution (ref 8, app C).

c. Position Location Reporting System (PLRS)

(1) PLRS is a computer-based system that provides position location and navigation information to a community of users and to the command and control elements of that community. It provides accurate, real-time, three-dimensional position location information of PLRS equipped airborne and ground elements. The system includes a limited digital message capability (refs 9 and 10, app C).

(2) The references just cited are the PLRS DT II Final Report and DT II Software Test, Final Report, Supplement 2. These two volumes are cited here as examples of post-test data analysis and reporting that are done for systems development tests. The final report contains 630 pages in the body of the report, plus an additional 610 pages in the 12 appendices; supplement 2 contains 176 pages in the body of the report plus an additional 42 pages in four appendices. There is considerable narrative concerning the test procedures and system performance, but there is also a considerable amount of space devoted to presentation of data in various formats, including plots and tables. Table I is a summary of the various means of data presentation in the body of the two reports (appendices not included).

TABLE I. DATA PRESENTATION IN PLRS FINAL REPORTS

	Plot, Printer	Plot, Plotter	Plot, Artwork	Data Table, Printer	Data Table, Typed	Data Table, Test Data
Final Report Supplement 2	108 18	37 24	18 0	32 2	190 87	2 0
Totals	126	61	18	34	277	2

(3) Some examples of the data plots and tables from those reports are shown in figures 5 through 10. Figure 5 is an example of a typical two parameter printer plot, with page number, figure number, and title typed on. Figure 6 is a histogram printer plot with typed page and title plus additional information on the test conditions. Figure 7 is a two parameter plot done on a plotter, again with title and page typed in. Figure 8 is a two parameter plot, but appears to have been done by a graphics artist by hand, rather than mechanically. Figure 9 is an example of a printer output of tabular data used directly in the report; finally, figure 10 is typical of the many presentations of tabular data that were done by typing or word processor.

(4) As noted, in most instances, the page number and possibly a figure number and title were typed on the plot or table after figure production. Of course, page numbers would be very hard to coordinate, but typing figure numbers and titles does mean an extra step in producing a report.

(5) The printer plots are sometimes hard to read because of imperfect originals; also they are sometimes slightly cryptic and require a bit of study to determine what is being presented; overall, the quality of printer plots is not as high as that done by plotter or artwork, if for no other reason than that the printing is small and sometimes imperfect.

(6) A gross analysis of the amount of automation used in producing these reports indicates that of 205 plots, 187, or 91 percent, were done by printer or plotter. There were approximately 313 tables, of which only 34, or 11 percent, were produced as printer output. Therefore, the PLRS reports are good examples of automating the analysis and presentation of large amounts of test data in the form of plots; it would appear that presentation of tabular data is still being done in several steps - drawing up of a table by the analyst, and thence to final form on a word processor.

d. Joint Tactical Information Distribution System (JTIDS)

(1) A presentation on ITIS support to Army JTIDS Class II Terminal DT/OT testing was made to the PLRS JTIDS Hybrid (PJH) Simulation Working Group in December 1982. It was assumed that testing will be conducted at Elgin Air Force Base in the time period June 1984 to March 1985 and that testing requirements would include repeatable scenarios, inputs with planned errors, and system stress.

(2) Development testing and operational testing both included interoperability as an important test objective. In summarizing ITIS features for this application, two points were that software exists, or can be modified at reasonably low risk; and the ITIS provides a complete capability for post-test analysis.

(3) The JTIDS testing is a probable future use of the ITIS and is an additional requirement to be considered if modifications of the current PTAS to a more automated system are undertaken.

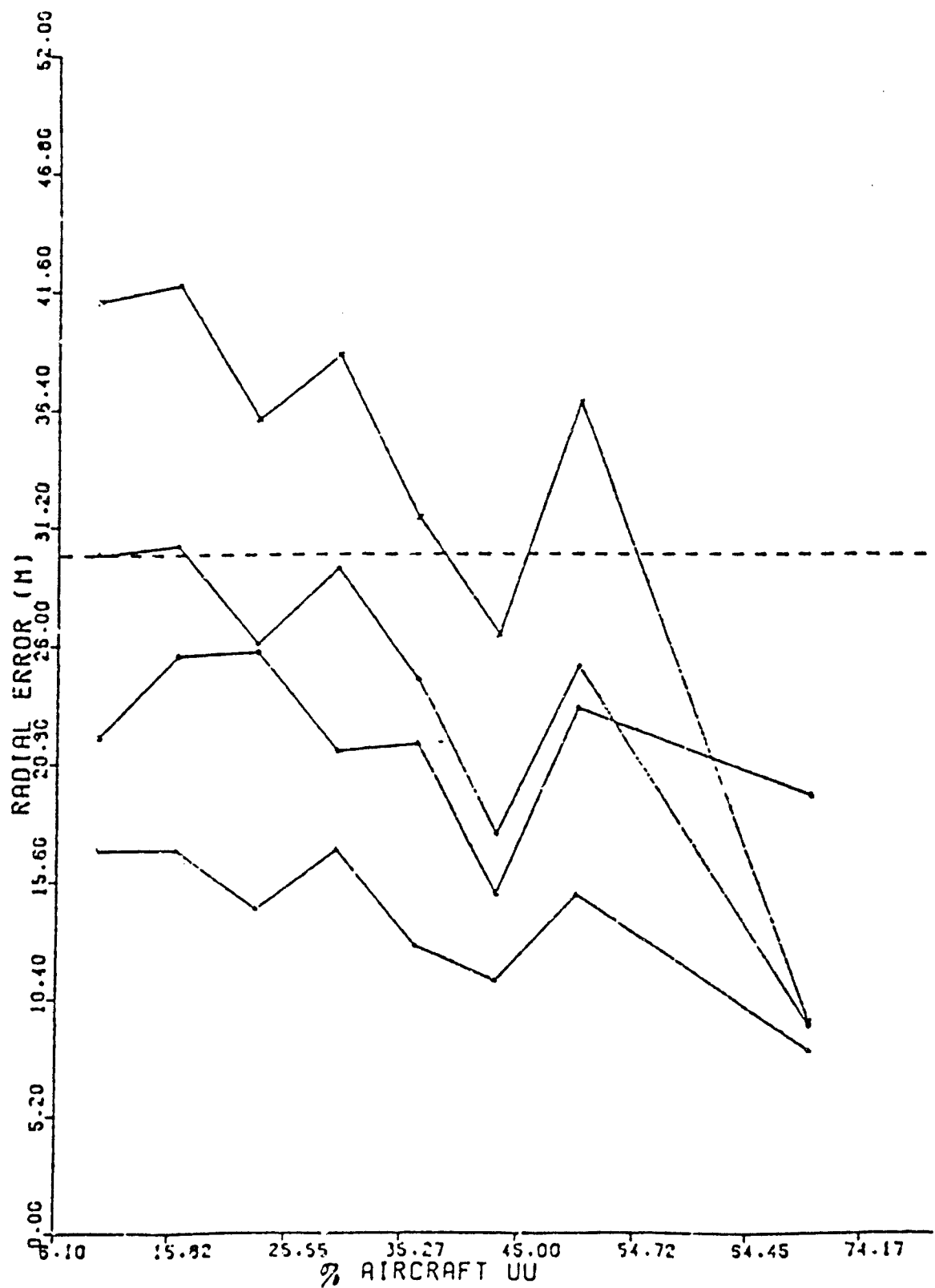


Figure 7. PLRS plot-radial error (ground) versus percent of AUs in the net (SIMPLRS).

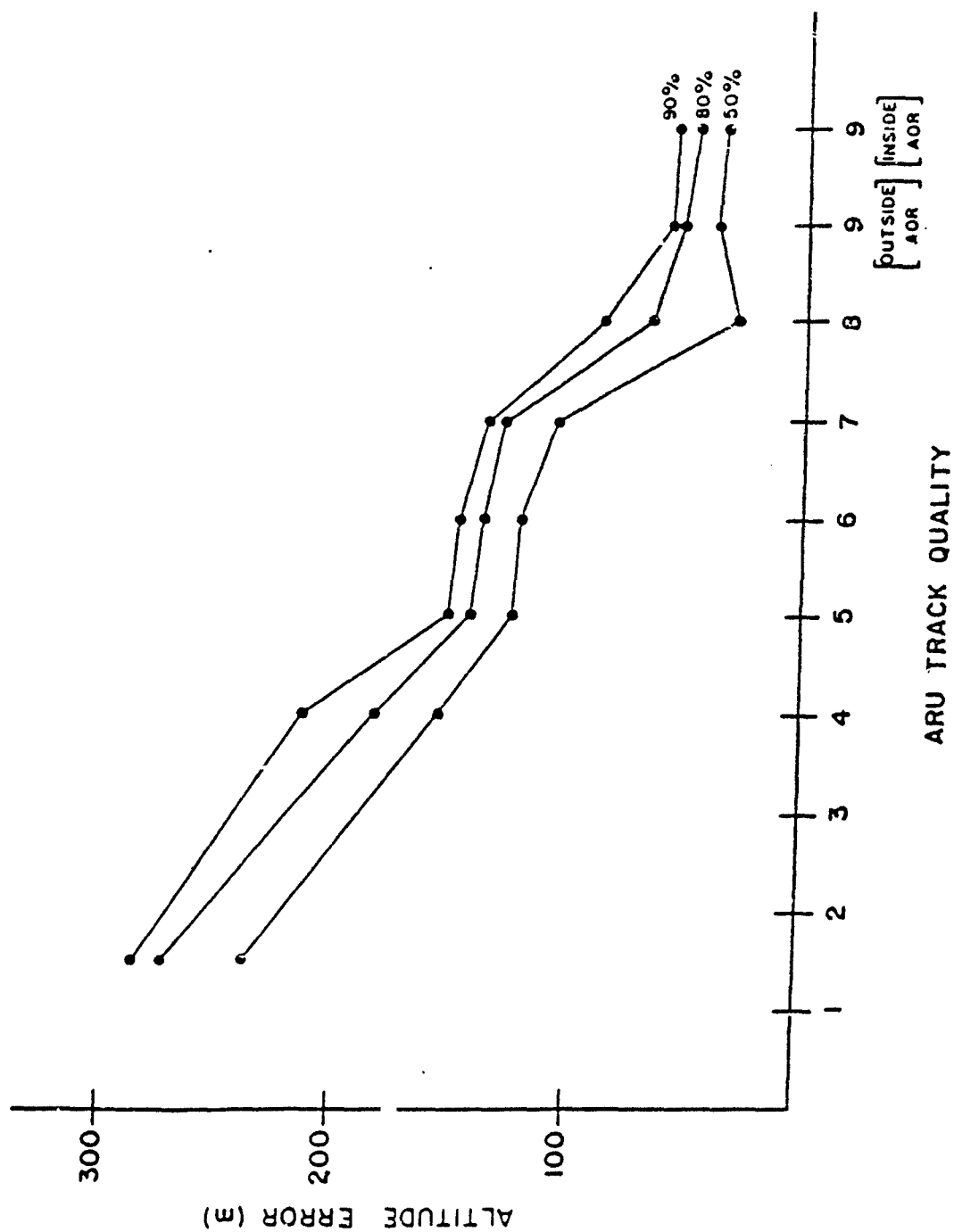


Figure 8. PLRS plot-altitude error (ARU) versus track quality (live).

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1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80																				

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TABLE 2.9.4-XI(S)
RADIAL ERROR BY UNIT TYPE (AFU) IN THE ABSENCE OF NOISE

PLRS-ID	Scenario and run	n	CEP 50%	80%	90%	mean	Time interval for CEP, mean	Time interval when AFU moving
0201	6ER1	126	9	13	20	14	(295-395)	(300-387) (318-377) $\bar{g} = .77$
	6ER2	125	8	13	18	16		
	6ER3	126	9	13	23	18		
	6ER4	125	7	11	15	12		
	6ER5	125	9	13	15	16		
0221	6ER1	126	7	16	28	21	(271-371)	(300-365) (300-365) $\bar{g} = .77$
	6ER2	125	7	17	21	19		
	6ER3	125	13	25	46	27		
	6ER4	126	7	11	15	12		
	6ER5	125	10	18	28	24		
0241	6ER1	125	5	9	13	9	(233-353)	(300-325) no curve
	6ER2	125	6	8	13	10		
	6ER3	125	5	9	13	9		
	6ER4	125	5	7	10	7		
	6ER5	126	5	6	9	7		
0261	6ER1	125	5	11	16	26	(265-365)	(300-365) (300-331) 1.34 to .53g
	6ER2	126	5	10	15	28		
	6ER3	126	4	11	19	31		
	6ER4	125	6	12	70	46		
	6ER5	125	5	11	14	36		
0281	6ER1	201	48	84	248	340	(300-470)	(300-466) (321-435) 4.02g's
	6ER2	157	45	109	206	417		
	6ER3	113	41	403	850	654		
	6ER4	*70	229	850	1023	1772		
	6ER5	203	46	69	93	309		

Figure 10. PLRS tabular data (example 2).

e. Joint Interface Test System (JITS)

(1) The Joint Interoperability of Tactical Command and Control Systems (JINTACCS) program involves testing a large number of diverse C3I systems for compatibility and interoperability. The JITS is a JINTACCS program. The C3I systems are at geographically dispersed locations.

(2) The JITS is an integrated system of many hardware and software components. The major software functions are test control, monitoring, simulation, data collection, and data reduction/analysis. Data collection includes message traffic, executed events, and status data. Data reduction/analysis includes on-line/real-time analysis, and post-test analysis.

(3) A more detailed breakdown of the data collection and data reduction/analysis functions performed by JITS are as follows:

(a) Data Collection

- 1 Initialization data
- 2 Test configuration data
- 3 Exercise ID and time reference
- 4 Executed events
- 5 Operator initiated test controls
- 6 System status
- 7 Comm circuit status
- 8 Messages exchanged on data links
- 9 Test notes
- 10 Equipment configuration
- 11 Equipment status
- 12 Detected event errors and access anomalies

(b) Data Reduction/Analysis

- 1 TADIL message reduction
- 2 TADIL message analysis
- 3 SRN target event history
- 4 Chaff event history
- 5 SRN admin point event history

- 6 Sim PU/RU event history
- 7 TADIL track event history
- 8 ESU history
- 9 TADIL link assignment
- 10 Executed events
- 11 Operator initiated test controls
- 12 Detected errors
- 13 Link quality data
- 14 Test notes

(4) The JITS also includes teletype (TTY) processing which does communication test conduct, communication test generation, and communication text analysis. The third function, communication text analysis, includes compatibility and interoperability (C&I) test analysis of message text and structure, and recording of analysis results for post-test reports. Some of the post-test analysis is done by manual selection of variables and desired plots/tables, in a manner similar to that of the current ITIS PTAS software.

(5) This information on JITS is presented as an example of the state of the technology of test data gathering and analysis as implemented in the nonpublic sector (private industry). The techniques and methodology used by this company can be used as a measure of the ITIS and its application to MCS and future systems, particularly in the areas of automation of test data collection and data reduction and analysis.

2.3 MCS USER NEEDS FOR AUTOMATED INTEROPERABILITY TEST DATA ANALYSIS (AIOPTDA)

The first objective of the methodology task is the determination of current MCS user needs for automation of interoperability post-test data analysis. This is discussed here in terms of specified requirements and current methods of MCS testing and analysis.

a. Specification Requirements on Post-Test Analysis. A number of documents must be considered when designing tests to determine the acceptability of performance of a system. For MCS testing, three types of governing documents have been identified. These are test design plans, including top level and detailed test design requirements, and specific test procedures for the SUT; performance specifications (A, B, and C level) of SUT; and specifications on the test driver system ITIS in this case.

(1) Test Design Documentation. These specifications include the TOP, IEP, TDP, and specific Test Procedures.

(a) TOP

1 The US Army Test and Evaluation Command (TECOM) TOP (Draft) Computer Software Performance Testing (ref 11, app C) lists the activities to be accomplished prior to doing tests; these include preparing for testing, conducting tests, and post-test analysis and reporting. This procedure does not tell how actions are to be done but rather attempts to list all actions that should be considered when planning to conduct a test. It includes a number of applicable checklists, data collection sheets, logs, software investigation report (SIR), and equipment performance report (EPR) forms to be used when planning and conducting tests and analyzing test results.

2 Early activities include definition of automated support tool requirements, definition of data reduction analysis (DRA) requirements, definition of data collection requirements, definition of scientific and engineering data processing support requirements, data reduction and analysis facilities acquisition, and acquisition of automated support tools.

3 The TOP requires implementation of a test configuration management plan, and lists the items to be included in the plan. Items of interest here are requirements for data reduction and analysis and data processing support, test data handling and labeling, and test related information, including logs, tapes, and checklists.

4 Detailed Test Procedures stress the need to determine the quantity and precision of the data in coordination with the Data Reduction and Analysis Team.

5 Data reduction includes requirements to transform test results to statistical performance measures compatible with test plan criteria, isolate performance exception measures to identify SUT performance anomalies, and the ability to merge data from different test categories.

6 Data analysis requires the use of statistical analysis techniques, histograms, regression and correlation analysis, and tests of significance. It further requires the use of prepackaged statistical analysis routines to minimize the amount of user generated code.

7 Data presentation requires a capability to present data in graphical and tabular form. It also requires multi-function plot capability, plot scale flexibility and appropriate labeling, and presentation of supporting data.

(b) IEP

1 IEP for the MCS (ref 1, app C) identifies the characteristics of the primary functional objectives of the MCS and the associated sub-objectives. Development testing is done to determine the capabilities and limitations of the MCS as they relate to those functional objectives. The IEP identifies the major functional objective of the force level and MCS to be the assurance of continuity of combat operations. To achieve this, five sub-objectives must be met: responsiveness, survivability/security, dependability, flexibility, and interoperability.

2 Interoperability identifies the critical issue as the ability of the MCS to interoperate with all systems required by the ABIC without causing mutual interference. The criteria for evaluation is that the MCS must demonstrate an ability to establish and maintain an information exchange without degrading its functional performance within its own functional area. The criteria for timeliness, accuracy and flexibility established for maneuver unit information processing must not be relaxed when interoperability is achieved with other Army systems, other services' systems, and other NATO systems. The systems with which MCS must interoperate (per this IEP) are:

a Maneuver Control Functional Area

- PLRS

b Other Functional Areas

- ASAS
- TACFIRE
- CSS C2
- SHORAD-C2
- AN/TSQ-73
- PATRIOT
- SOTAS

c Other Services' Systems

- WWMCCS
- TCO
- ITAWDS
- TACC CAFMS

d Allied Systems

- WAVELL
- HEROS
- TACCDAS

3 Data requirements and sources are identified as follows: data on transmission errors, format errors, transmission delays, CPU demands, message volume, translation/reformat times, and response times for information requests for MCS will be collected when interoperating with each system for which an interface has been specified and implemented for each of the following conditions:

a MCS is tasked to interoperate with other systems and has no maneuver control demands placed on it.

b MCS is operating under a most likely scenario load of tasks.

c MCS is operating under a worst case loading.

The method of evaluation will be to analyze test data to determine if timeliness criteria for the interface and for MCS primary functions are satisfactorily met.

(c) TDP

1 The TDP (ref 13, app C) serves as an outline for the required testing to be done during Government development tests. The primary objectives of the plan are minimization of testing time and sample size, elimination of unnecessary or repetitive testing, and maximum usage of obtained results in evaluation of system performance. It requires that mathematical and statistical procedures be used on test data, and that results obtained with these techniques be used in evaluating MCS performance regarding categories in the IEP and in determining compliance with requirements of the ROC document.

2 Concept of test lists three questions to be answered regarding interoperability: Can the MCS interoperate with the systems as outlined in the ROC?, Can MCS interoperate with these items as specified?, Are the specified levels of interoperability (automated, human, etc.) currently in existence or soon to be?

3 General approach includes use of the ITIS to satisfy testing requirements. It lists three main functions of the ITIS, including scenario generation, real-time testing, and providing post-test data reduction/data analysis capability. The last sentence of the paragraph requires that all data reduction and statistical analysis outlined in the TDP should be provided using the UCLA BMDP-79.

4 The main TDP requirement on interoperability testing states test objectives to be to ensure that the MCS and each of its interoperating systems (as specified in the ABIC) have implemented an interface and achieved compatibility and can interoperate without mutual interference.

5 It requires tests to be run with the MCS interoperating with one or more systems in each of the following conditions:

- a MCS having no maneuver control demands placed on it.
- b MCS minimally tasked with maneuver control functions.
- c MCS operating under a most likely scenario load of tasks.
- d MCS operating under a worst case loading.

It should be noted that the second item is an additional requirement over those stated in the IEP.

6 The paragraph on data requirements/data presentation states that the test report shall provide:

- a Number and type of transmission errors for each message type.
- b Number and type of format errors for each message type.
- c Transmission delays for each message type for each system for each set of test conditions.
- d The volume and frequency of messages by message type from each node of each system and to each node of each system.
- e The response times of each specific type of demand made on MCS and by MCS for each set of test conditions.
- f A description of the integrated prioritization of demands (both internally and externally generated) for MCS to service (prioritization specified by the proponent) and the results of tests run to demonstrate that the prioritization has been implemented.

7 The following paragraph does not address interoperability requirements directly, but is mentioned here as additional information. Paragraph 3.2.1.1, System Performance, sub-issue k, communications compatibility and sub-issue 1, multiple peripheral devices, present some additional requirements in their sections on data requirements/data presentations. For example, item k, (3) 9 states that error statistics for messages sent/received across the interface both with and without error control encoding are required.

(d) IEP/TDP for the TCT and TCS. This document (ref 12, app C) was reviewed since the MCS is actually composed of combinations of TCTs and TCSs. In section II, the IEP portion, section D, data requirements, the

discussion is very general, and does not specifically address compatibility or interoperability testing. Likewise, in section III, the TDP, the subjects interoperability, data requirements/data presentation are nowhere addressed. Therefore, this document does not identify any user needs or requirements for automation of post-test data analysis.

(e) SUT Specific Test Procedures

1 USAEPG Test Procedure 2.5.5, Message Prioritization (ref 16, app C) is considered here as an example of the detailed document that is required to run each test. This document contains 130 pages, of which 108 pages are detailed step-by-step instructions for the test operator. However, there are 10 pages on scenario requirements which specify details on the time of a message, its source, destination, and precedence. This information is used in building the message scenario tape.

2 Testing and post-test data reduction and analysis are separate functions; the main item of interest is the generation of the test data base (tape or other) and the availability of that data base for the data reduction and analysis function. Therefore, the specific test procedure affects automation of interoperability test data analysis to the extent that it allows quick availability of a test data base, and that it influences the selection of the format and medium of the test data base.

(2) MCS Performance Specification

(a) In general, one would expect that there would be a performance specification on the MCS with detailed performance requirements to be met by the item as delivered by the supplier. For example, the PLRS Final Report references a NAVCON document that appears to be the PLRS performance specification. To date, no single document has been identified as being the MCS System Specification. However, the first part of the TDP (ref 13, app C) includes a paragraph 1.3, Proposed System Requirements, taken from a draft ROC, which appears to be the actual requirements to which the MCS was designed and built.

(b) The main requirements of interest are the following:

1 Exchange information between all echelons from battalion to corps. The priorities of the information areas are mission, friendly situation, operational environment, and enemy situation.

2 Provide for continuity of operations to insure that critical information will be available at command posts when devices servicing the command posts and/or communications supporting those devices fail or are being moved.

3 Be capable of utilizing existing and planned Army tactical communications as of 1985 and must not create a unique electromagnetic signature when introduced.

4 Provide:

a A capability to edit, compose, and validate messages. Prompts to assist message composition, to include error prompts, will also be provided.

b When loads exceed peak, discontinue message processing and the flow of information items in inverse order of precedence. The lower priority items must be retained in storage at the originating device and be transmitted when the load decreases, unless purged by the system. The local device must be notified that the data has not been transmitted.

5 Be capable of interoperating with systems as identified in the ABIC.

6 Be capable of simultaneous reception and transmission of information without interference with message preparation.

(3) Test Driver (ITIS) Specifications. The performance requirements of the ITIS, the system currently being used for MCS interoperability testing, are contained in a number of specifications. The area of post-test data analysis is covered in Computer Program Configuration Item (CPCI) Specification, Communications Applications Real-Time Remotely Operable Test System (CARROTS) for Tactical Automated Test, Evaluation, and Reporting System (TATERS) (ref 14, app C) and in CPCI Specification, Post-Test Evaluation Analysis and Reporting System (PEARS) for TATERS (ref 15, app C).

(a) CARROTS Specification

1 This specification is mainly concerned with the real-time test driver, which includes generation of the test log tape. The information on the log tape is the input data to the post-test analysis system.

2 CARROTS Log Tape Interface presents a figure showing the CARROTS log tape format, and a table showing the CARROTS log tape data. The data item shows the log tape records contents, and indicates three types of records: header, data, and trailer.

3 The CARROTS specification is dated 18 July 1979 and presents the state of the log tape formats at that time. The Bell Technical Operations Letter, subject: Sample ITIS Test Data, dated 19 November 1982 (ref 4, app C) gives more detailed information on the log tape formats. These include a test identification record and a test description record at the start of the tape, eleven different types of message and message related records, and an operator log record and a trailer record at the end of the recorded data. This letter also includes much information on record content although it is not complete. The record identifications and associated channels are shown in table II.

TABLE II. MESSAGE LOG TAPE RECORD TYPES AND CHANNELS

Channel	Record Type
10	Test Identification
11	Test Description
30	Input Transmit Message
31	Transmit Message or Service Message
32	Transmit Acknowledge Message
42	Decoded Transmit Acknowledge
33	Received Message and Service Messages
43	Decoded Received Text Message
34	Received Acknowledge Match
44	Decoded Received Acknowledge Match
35	Received Acknowledge No Matches
45	Decoded Received Acknowledge No Match
46	Decoded Received Service Message
40	Operator Log Records
51	Trailer Record

(b) PEARC CPCI Specification

1 This specification (ref 15, app C) established the functional requirements for performance, design, test, and acceptance of the post-test evaluation, analysis and reporting system. This system is required to generate reports containing information necessary for analyzing and evaluating MCS performance in response to scenarios on the MST. This specification required the PEARC to read and analyze both MST and MLT. The following reports were required to be generated by the PEARC: message log presentation, time/event synopsis, test configuration report, exceptions report, graphics/data messages reports, and statistical analysis report.

2 The PEARC specification is dated 2 October 1979 and reflects the state of the post-test analysis system as of that date. The PTAS User's Manual (ref 5, app C) gives more up-to-date information on the current capabilities of the post-test analysis system on ITIS. These are discussed more fully in paragraphs 2.2a and 2.3b(2).

b. Current Testing and Analysis. The current MCS testing is done using various configurations of TCSs and TCTs and a number of different scenarios. The post-test analysis of the data, as it is being done at present, uses some of the available features of the post-test analysis system. The testing and analysis are discussed in the following sections.

(1) MCS Interoperability Testing

(a) Paragraph 3.1 of the MCS TDP (ref 13, app C) specifies two MCS configurations to be used during interoperability testing. Subtest I uses one TCS and one TCT; Subtest II uses three TCSs and three TCTs. Subtest III is the same configuration as that of subtest II, but requires testing in a more representative tactical field environment using existing communications. In addition, the TDP states that use of the ITIS whenever necessary to satisfy testing requirements is implicit in the test plan.

(b) The message scenario tapes were used to conduct a number of different types of tests, including peak load, message reception, and message prioritization tests. These tapes include information on ten types of tests; the test type and number of tests for that type are shown in table III.

TABLE III. MCS SCENARIO INFORMATION

Test Type	Number of Tests Run
Peak Load	59
Message Reception	47
Message Prioritization	47
Remote User Impact	31
Message Prep Interface	26
Miscellaneous (Dry Run or MCS System Checkout)	26
DBMS	8
Initialization	7
Networks	3
Distribution Lists	2
Total Number of Tests Run	256

(c) Some information on the content of the message log tape was presented in paragraph 2.3a(3)(a). As indicated there, the test data include up to eleven different types of message and message related records. The contents of each of these record types is given in the Bell Technical Operations letter (ref 4, app C).

(d) If there are an average of 300 messages per run, then the total number of messages to be processed and analyzed is on the order of 75,000. This quantity of tests and messages is such that a complete and thorough data reduction and analysis requires further automation of the PTAS process.

(2) Test Data Analysis

(a) Two primary pieces of information available to the analyst, when assessing SUT performance, are the test procedure and the message log tape. Also, there would be printed outputs from the TCS and test conductor log. The tool available to do MLT analysis is the PTAS. The analyst must be familiar with the test objectives, SUT and test driver configurations, and expected outputs to do a proper evaluation of SUT performance.

(b) The PTAS enables extraction of selected information from the MLT and presentation of that data in a suitable format, e.g., dump, tabular, plot, or histogram. Use of the PTAS is described in the PTAS User's Manual (ref 5, app C). In addition, the PTAS allows creation of a file in the proper format so that the Biomedical Data Package (BMDP) software package can be used to do statistical analysis and plotting the data.

(c) As already discussed in paragraph 2.2a, the analysis of data using PTAS is controlled by the specification of inputs for up to five control tables: format, primary variable, dump, table, and plot. The PTAS User's Manual shows sample runs to build the five control tables; in the samples shown, the user/operator must enter information on the number of lines shown as follows:

Format Control Table	17
Primary Variable Control Table	11
Dump Control Table	10
Table Control Table	10
Plot Control Table	15

(d) These are approximate minimums required, and for dumps/tables/plots having more variables, more entries are required. Thus, the current PTAS software has two significant features: it is very flexible as to selection of inputs and outputs; this very flexibility means that the current PTAS system is labor intensive, requiring 35 to 40 or more entries by a user in order to get a product.

(e) The first sentence of paragraph 2.5 of the PTAS User's Manual states that "the PTAS provides an automated general-purpose data reduction capability for the ITIS." Thus "automation" of post-test data analysis would seem to be open to some interpretation, and perhaps a strict definition of "automated" interoperability post-test data analysis is needed. In ITIS testing and data reduction and analysis, automated means the generation of a predetermined set of analysis products with a minimum number of operator inputs (e.g., 5 or less). In view of the many operator inputs required by the current PTAS, it does not appear to be a fully automated system, but rather a semi-automated system with built in flexibility to allow analysts to change inputs and outputs as the analysis progresses.

(f) The above information is indicative of the PTAS system as it was designed and coded. However, discussion with personnel doing the analysis of the current MCS test data indicates that most of the features discussed are not being used; in fact, the current PTAS usage is limited to production of log tape dumps with the following information: input transmit message, decoded transmit acknowledge, decoded received text message, decoded received acknowledge match, decoded received acknowledge unmatched, decoded received service message, test identification, and test description. Of this tape dump, some comparisons among fields are being done to produce tabular data by hand; no computer generated plots are being done. Thus, there is only small usage of even the present PTAS capabilities. It should be stated here that these facts are to some extent influenced by the particular performance of the SUT in test (MCS) and that for other SUTs the amount of usage of the PTAS could be more complex and complete. A well designed and automated PTAS will function and generate useful products even if the SUT is working poorly, hanging up or aborting the test for other reasons.

2.4. AUTOMATION OF POST-TEST DATA ANALYSIS

The second objective of the AIOPTDA task is the proposal of an appropriate approach for the automation of interoperability post-test data analysis for the MCS. The approach would provide an effective method for reduction and analysis of typical test data from a large data base generated during interoperability testing. Two approaches are discussed in this section. The first is an extension of the present PTAS to make it more fully automated. The second is the use of embedded query calls in a commercially available data base management system.

a. Extension of Current PTAS. The method of operation of the PTAS is outlined in the PTAS User's Manual (ref 5, app C), and has already been discussed in paragraphs 2.2a and 2.3b(2). The essential elements of operating PTAS are shown in figure 3; operator inputs are done in an interactive mode, using the PTAS to extract information from the message log tape. The PTAS outputs are dumps, tables and plots, or save files. The information in save files can be used as inputs to the BMDP package for further statistical analysis and plotting.

(1) Use of Runstream

(a) The proposal to use an extension of the current PTAS uses a predefined runstream to perform automatically the operations and inputs that would be done by an operator sitting at a terminal. The runstream is a file whose contents emulate the actions an operator would take when running the PTAS software, or more generally, when generating a product (dump, table, plot, save file) using the MLT data as input. The runstream exists as a stand alone program, and when initiated, will require a minimum number of inputs, e.g., input message log tape number or the tape drive on which it is mounted. Each runstream would have a predefined output, either a single dump, table or plot, or some combination of these; else it would create a save file and automatically call the BMDP software for further processing. Actual implementation of such a scheme is hardware and operating system dependent, but has already been done on two systems to this writer's knowledge (a Varian mini and Univac large frame) and has probably been done on others.

(b) The main features of the predefined runstream are inclusion of all calls to stand alone programs, inclusion of all data inputs required (pseudo operator inputs), and a fixed (predetermined) output or set of outputs. This method of automating post-test data analysis uses the test data in the form as it is currently created: either in a disk file or on magnetic tape. Further, present PTAS software is used as it exists at present or with only minor modifications to the main programs.

(2) Definition of Outputs

(a) Automation of data processing has an immediate implication for those who would like to retain great flexibility when doing data analysis: some of the flexibility must be surrendered. The very nature of the automating process requires hard definitions of the output products desired.

(b) A large number of message log tapes were generated during the DT testing. One usage of PTAS was to generate a standard dump of selected data from those tapes for use by the analysts. Thus, there has been an evolution to one type of standardized output already. It is this type of standardization or output product definition that must be done for further implementation of automation of the MCS test data processing. Once a desired output product has been defined, it is a straightforward process to define the runstream required to produce that product.

(3) Use of BMDP. The use of a runstream to run the PTAS software can include the automatic creation of a save file for BMDP use. The runstream would include the call to the required BMDP software package to do the statistical analysis or plotting desired. (See the right side of figure 3.) The important point to note as before is the need to have predefined the output product or products that are required.

(4) Implementation Resources Required

(a) There are five areas of consideration when implementing the above scheme for automation of test data analysis:

- 1 Data base definition
- 2 PTAS software definition
- 3 Runstream implementation
- 4 Output product definition
- 5 Demonstration of the scheme

(b) The first item, data base definition, would require little or no modification to the present data base. At most, it might be desirable to be able to operate directly off of the log data on disk rather than after it has been dumped to tape. At any rate, a minimal effort is required in this area.

(c) The second item, the PTAS software, likewise should require only minor modifications to allow operation in this mode. The inclusion of the BMDP capability might add some effort required to this task, but should be of a similar magnitude to the PTAS mods. The modifications required are those related to the transition from an interactive terminal with operator inputs to automated inputs on a pregenerated parameter file. The main point is to keep the PTAS and BMDP software modular and general so that the same modules are used in each runstream or command file with only the input parameter files being different.

(d) The third item, the runstream implementation, as already pointed out, is hardware and operating system dependent. In the usual situation, a small effort by the system programmer should be sufficient to allow implementation of this mode of operations, if it does not already exist on the system.

(e) The fourth item, output product definition, will be the most difficult one to accomplish. It will require inputs and cooperation of all those responsible for determining how well the SUT meets its performance requirements, including the test conductor, analysts, and report writers. It is difficult to estimate the extent of effort required to accomplish this; in part, it would at first be an on-going effort until satisfactory products had been identified.

(f) The fifth item, demonstration of the scheme, is done as soon as the first three items have been accomplished and at least one end product has been identified. This demonstration serves as proof of the feasibility of automating the test data analysis in this manner.

b. Alternate DBMS. The approach to automation presented in paragraph 2.4a is based on the present ITIS configuration where there are two data bases, one for message scenario tape generation and the second containing the log tape data. Here we consider an alternate scheme where the two data bases are replaced by one data base, probably a commercially available DBMS.

(1) DBMS Features

(a) The current generation of DBMSs include a number of features of interest for this study. These features include data base structure, inclusion of query and embedded query language, and inclusion of a data analysis/graphics package.

(b) The three models used in the representation of data are relational, network, and hierarchical. A comparison of these models is not appropriate here; a discussion is provided on pages 168-170 of Principles of Data Base Systems (ref 18, app C). One point of the reference is that for smaller data bases, on the order of thousands or tens of thousands of records, ease of use is a prime consideration and, in this case, the relational model is the best. Writing applications programs and phrasing queries is easier and can be done by persons with lesser programming skills in the relational model. For larger data bases, where efficiency of implementation is an important factor, the network and hierarchical models are better. On the basis of the quantity of messages presented in paragraph 2.3b(1), the current ITIS data base falls into the smaller category with thousands of records per MCS test. However, this sizing could grow if other systems are tested (e.g., TACFIRE) and also if test data are allowed to accumulate on the data base.

(c) Data definition and data manipulation are done by a data manipulation language, commonly called a query language. In a relational data base, the query language is non-procedural; the user specifies what is to be done, but not how it is to be done. Such a language allows the following operations on the data base:

1 Data Definition

- a Create tables
- b Destroy tables
- c Modify storage structures
- d Add or delete secondary structures

2 Data Manipulation

- a Print tables
- b Retrieve data from tables based upon conditions
- c Append rows to tables
- d Delete rows from tables
- e Change data in tables

(d) For post-test data analysis, the operation of most interest would be the second one under data manipulation, the retrieval of data from tables based on some set of conditions.

(e) The third feature of current DBMSs is the inclusion of a data analysis/graphics package. Selection of a DBMS with such a feature would allow a direct tie-in of the query language with the generation of graphics data. For example, the Interactive Graphics and Retrieval System (INGRES) graphics package allows several graph types including bar charts, pie charts, scatter plots, and general line graphs; and other features, including headings, legends, cross-hatch patterns, dot types, line types, type faces, titles, linear regression for scatter plots, scales for quantities including a logarithmic scale and tick marks for various scales. This package is supported on a number of output devices, including DEC VT125, Tektronix 40XX, AED 412/767, and RAMTEK 62XX terminals; Zeta, Calcomp, and Hewlett-Packard plotters; and the Dicomed film recorder.

(2) Post-Test Data Analysis on a DBMS

(a) How do we do post-test data analysis when the data are sitting in a general data base? That is the question to be addressed here. As already noted, current generation DBMSs will have some sort of query language for retrieval of selected data; in addition, we shall require that the DBMS will have an embedded query capability. This means that the query commands can be embedded in an applications or host program written in a high order language (HOL) such as Fortran, Cobol, Basic, Pascal, or C. The key to this capability is the availability of a preprocessor or precompiler which replaces the query language calls with normal HOL calls after which the code can be compiled in the normal manner.

(b) The philosophy here is to avoid rewriting the PTAS data selection software in terms of the query language; instead, we want to write an applications program for each analysis product identified. After all, the premise above is that query is easy to use, especially with a relational data base; in effect, we are replacing the PTAS data selection software with the use of the query language.

(c) As to the resources required to implement this approach, highly sophisticated programmers should not be required for implementation, and the total cost would be directly proportional to the number and complexity of products requested.

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SECTION 3. APPENDICES

APPENDIX A. METHODOLOGY INVESTIGATION PROPOSAL

1. TITLE. Automation of Interoperability Test Data Analysis.
2. CATEGORY. Interoperability Tests.
3. INSTALLATION. US Army Electronic Proving Ground, Fort Huachuca, Arizona 85613.
4. PRINCIPAL INVESTIGATOR. Max Sanders, Software and Automation Branch, STEEP-MT-DA, AUTOVON 879-6957, 6058, 6870.
5. STATEMENT OF THE PROBLEM. A rapidly increasing number of automated C-E systems are being developed for use by the field army. The comprehensive testing of the interoperability of these complex systems is critical to their performance evaluation. Such testing will generate large volumes of test data. Manual analysis is incomplete, time impractical, and excessively costly to conduct. Automated data analysis test methodologies must be developed which will optimize the use of automated data analysis technology to provide a complete, timely, and economically practical evaluation capability.
6. BACKGROUND. The Army and DOD have developed and are continuing to develop a number of major automated C3I Systems. These include TACFIRE, MCS, TCAC, TCS/TCT, AN/TSQ-73, REMBASS, SOTAS, and ASAS. These systems are designed to interface with a large number of interactive systems and to operate in a highly interactive environment. The critical element in the success or failure of these C3I Systems will be their interoperability and performance under load in a highly interactive tactical environment. The nature of interoperability testing results in the generation of large volumes of data. A need exists to develop an automated data analysis capability. The enormous cost of manual analysis, both in dollars and test period, is prohibitive. Additionally, the added probability of multiple errors in manual analysis makes such analyses questionable. The Army is developing major systems with a critical role in the combat effectiveness of the 1982 and beyond field. The inability to automatically analyze and evaluate the data generated in interoperability testing is a risk that the Army cannot afford to take.
7. GOAL. This investigation will develop comprehensive and cost effective test methods for reducing and analyzing the large volume of test data generated during interoperability testing of automated field army C-E systems.
8. DESCRIPTION OF INVESTIGATION
 - a. This investigation will provide the foundation for the analysis of interoperability test data for the Army. The investigation will identify critical data analysis deficiencies and develop solutions to resolve them. The data that needs to be collected will be identified, and the manner in which it can be correlated to the input will be determined. This is to include providing traceability from output data through the input and back to the specification. A generalized solution to the complex problem of analyzing these large amounts of data will be sought such that a cost effective but empirically validated interoperability evaluation results.

b. USAEPG will conduct the overall investigation in two phases. Phase I will cover a basic problem analysis and solution study and Phase II, a measurement system design development.

(1) Phase I

(a) Current Technology Search. A review of existing reportage covering data reduction and analysis to include requirements documents for the 1982-1992 time frame automated tactical C-E systems.

(b) Problem Definition. The separation and determination of the key data analysis deficiencies which prevent the effective assessment of the data collected. This is to include the determination of the data which must be collected.

(c) Solution Development. The identification and evaluation of potential solutions and the detailing of the particular set of data collection, reduction, and analysis techniques required. Economic as well as technological problems will be addressed.

(2) Phase II

(a) Measurement Requirements. The development of the manner in which the output can be correlated with the input and specifications. This will provide traceability from output data through the input and back to specification.

(b) Measurement System Design. Developing the detailed design of the overall data analysis system. The system will incorporate current USAEPG capabilities to the extent possible. Selection and purchase of analysis capabilities will also be considered. Methodology for validating the chosen approach will be included.

c. USAEPG will conduct the investigation as follows:

MILESTONE/PHASE	SCHEDULE							
	FY 82 (Qtrs)				FY 83 (Qtrs)			
	1	2	3	4	1	2	3	4
Current Technology Search	x	x						
Problem Definition		x	x					
Solution Development				x				
Measurement Requirements						x		
Measurement System Design						x	x	x
Report								x

d. The investigation will result in establishing procedures for analysis of interoperability testing data. The procedures will provide utilization of automatic data analysis techniques in interoperability evaluations.

e. Environmental Impact Statement. Execution of this task will not have an adverse impact on the quality of the environment.

f. Health Hazard Statement. Execution of this task will not involve health hazards to personnel.

9. PROGRESS. New investigation.

10. JUSTIFICATION

a. Mission and Impact Statement

(1) Association with Mission. USAEPGs primary mission is to conduct development testing of C-E equipment and systems. In support of this mission, USAEPG has developed extensive experience in compatibility, vulnerability, electronic warfare, and intelligence testing, automated system (software) testing, and more recently pioneered efforts in interoperability testing. Automated data analysis represents the logical extension and syntheses of interoperability testing. Development of automatic analysis methodology will allow an effective utilization of testing data. Without this methodology, the analysis must be accomplished by manual means.

(2) Present Capability, Limitations, Improvement, and Impact on Test if Not Approved. USAEPG has a number of key methodology instrumentation and test facility elements required for a successful interoperability test capability. These elements, however, do not have an automatic test data analysis. To provide a cost effective data analysis capability, the current manual capabilities at USAEPG must be upgraded to automated data analysis methodology. If this task is not approved, USAEPG will have to reduce data by manual means at an enormous cost in manhours and extended test periods.

b. Dollar Savings. No direct cost savings can be computed at this time. However, experience has demonstrated that the only alternative to the proposed automated data analysis approach is manual analysis. It is conservatively estimated that the latter could easily consume one-third of USAEPGs fiscal resources for the entire year for one major C3I system interoperability test.

c. The following major field army automated systems are currently under development and are programmed for testing during the 1982 to 1992 time frame.

(1) Intelligence Systems

All Source Analysis System
Automatic Meteorological System
Standoff Target Acquisition System
Remotely Monitored Battlefield Sensor System
Remotely Piloted Vehicle
Electro-Optical Control Analysis and Reporting System
Remote Automated Weather System
Classified Interfaces (8)
TRAILBLAZER

(2) Electronic Warfare Systems

Multiple Target Electronic Warfare Systems
Tactical Jammer
Unattended Expendable Electronic Countermeasures
Close Air Support Electronic Countermeasures

(3) Command and Control Systems

PATRIOT CCS/ECS
Maneuver and Control System
Nuclear Burst Detection System
Tactical Computer System
Tactical Computer Terminal
FIREFINDER
Multiple Launch Rocket System
SHORAD

(4) Communications/Navigation

Position Location Reporting System.
Global Positioning System
Joint Tactical Information Distribution System
Mobile Subscriber Equipment
Army Data Distribution System
Source Data Automation

d. Recommended TRMS Priority. Refer to the preceding workload paragraph and the ODCSOPS priority list.

e. Association with Requirements Documentation. The Army Battlefield Automation Interoperability System Engineering Management Plan (BAISEMP), dated November 1978, outlines the requirements for interoperability testing. ABIC, dated December 1979, the draft ABIC 80, and the ACCS Implementation Plan provide further requirements details.

APPENDIX B. DEFINITIONS

ABIC	Army Battlefield Interface Support
ACCS	Army Command and Control System
AIOPTDA	Automated Interoperability Test Data Analysis
ATDL	Army Tactical Data Link
BAISEMP	Battlefield Automation Interoperability System Engineering Management Plan
BMDP	Biomedical Data Package
CARROTS	Communication Applications Real-Time Remotely Operable Test System
C3I	Command, Control, Communications, and Intelligence
CPCI	Computer Program Configuration Item
CPU	central processing unit
C-E	communications-electronics
C&I	compatibility and interoperability
DBMS	data base management system
DOD	Department of Defense
DRA	data reduction analysis
DT	Development Test
ECCM	electronic counter-countermeasure
ECM	electronic countermeasure
EPR	equipment performance report
FAST	Functional Area System Test
FATDS	Field Artillery Tactical Data Systems
GDBMS	generalized data base management system
HOL	high order language
IEP	Independent Evaluation Plan
INGRES	Interactive Graphics and Retrieval System
ITIS	Interim Test Item Stimulator
JINTACCS	Joint Interoperability of Tactical Command and Control Systems
JITS	Joint Interface Test System
JPL	Jet Propulsion Laboratory
JTIDS	Joint Tactical Information Distribution System
MCS	Maneuver Control System
MFL	Message Format Library
MLT	message log tape
MOP	measures of performance
MST	message scenario tape
NVVT	New Version Verification Test

PEARS	Post-Test Evaluation, Analysis, and Reporting System
PJH	PLRS JTIDS Hybrid
PLRS	Position Location Reporting System
PTAS	post-test analysis system
ROC	Required Operational Capabilities
SIR	software investigation report
SOS	Standard Operating System
SSG	Software Support Group
SUT	system under test
TACFIRE	Tactical Fire Direction System
TADIL	Tactical Digital Information Link
TAR	Test Anomaly Report
TATERS	Tactical Automated Test, Evaluation, and Reporting System
TCAC	Tactical Command and Control
TCS	Tactical Computer System
TCT	Tactical Computer Terminal
TDP	Test Design Plan
TECOM	US Army Test and Evaluation Command
TMDB	test message data base
TOE	Table of Organization/Equipment
TOP	Test Operation Procedures
TPR	TACFIRE Problem Report
TSSG	TACFIRE/FATDS Software Support Group
TTY	teletype
USAEPG	US Army Electronic Proving Ground

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